INFLUENCE OF VEHICLE PROPERTIES AND HUMAN ATTRIBUTES ON NECK INJURIES IN REAR-END COLLISIONS

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ABSTRACT

While traffic accident fatalities in Japan have been declining, the number of injuries has continued on an upward trend for many years. One salient aspect of that rising trend is the number of casualties attributed to rear-end collisions. In 2005, such accidents accounted for approximately 35% of all fatalities and injuries. Regarding ordinary passenger cars, many of the drivers of the struck vehicles in rear-end collisions suffer slight neck injuries, while nearly all of the drivers of the striking vehicles are not injured. In this study, the influence of vehicle properties and human attributes on the incidence of neck injuries in rear-end collisions was analyzed using an integrated accident database developed by the Institute for Traffic Accident Research and Data Analysis (ITARDA). The results revealed, among other things, that an active head restraint system, which is one type of anti-whiplash device, is effective in suppressing the occurrence of neck injuries; that females tend to be injured more often than males; that age and generation influence the tendency for men to be injured; and that the trip purpose influences the tendency for neck injuries to occur. This tendency for generation and trip purpose to exert such an influence suggests the possibility that the health consciousness of the parties involved in rear-end collisions might affect the incidence of neck injuries. Among the other issues discussed in this paper is the concern that neck injuries due to rear-end collisions might increase in the future.

INTRODUCTION

In Japan, the number of traffic accident fatalities occurring within 24 hours totaled 11,451 in 1992. It has decreased consistently since then, falling to 7,358 in 2004 and to 6,871 in 2005. The number of fatalities occurring within 30 days has also steadily declined, dropping to 8,492 in 2004 and to 7,931 in 2005 as shown in Figure 1. This decrease is thought to result from various measures, including more extensive traffic safety education, road and vehicle improvements and better emergency medical care [1-3]. In contrast, the number of traffic accident injuries has been increasing for many years, totaling more than 1.1 million annually in recent years as shown in Figure 1, so further measures to reduce injuries are necessary.

This study focused on rear-end collisions which account for many traffic accident injuries. The situation (as of 2005) for rear-end collisions in Japan and resultant neck injuries was analyzed using an integrated accident database developed by the Institute for Traffic Accident Research and Data Analysis (ITARDA). And the influence of vehicle properties and human attributes on the incidence of neck injuries in rear-end collisions was analyzed using an integrated accident database.

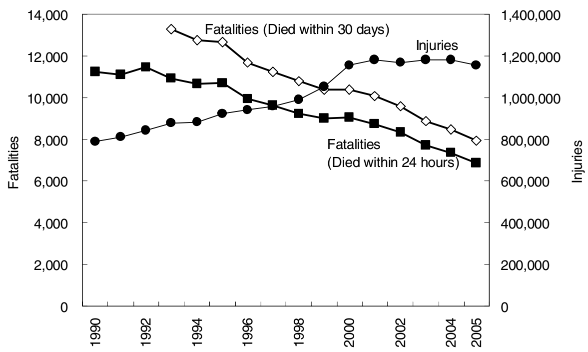

Figure 1. Trends in traffic accident fatalities and injuries.

ACTUAL SITUATION FOR REAR-END COLLISIONS AND INJURIES

Rear-end Collisions

The trends in the number of traffic accidents by type are shown in Figure 2. Rear-end collisions show a marked upward trend and have consistently been the most numerous of all types of traffic accidents since 1996. In 2005, they accounted for approximately 32% of all traffic accidents. Figure 3 shows the trends in the number of casualties by type of accident. The number of casualties occurring in rear-end collisions has also tended to increase and accounted for approximately 35% of the total in 2005.

Limiting rear-end collisions to the combination that the striking vehicle is the primary party (culpable) and the struck vehicle is the secondary party (less culpable), the number of such combinations that year was 263,993. The combinations are broken down by vehicle type in Table 1. According to the table, the number of rear-end collisions in which the striking vehicle was an ordinary passenger car was 156,324, or approximately 59%. Of them, the number of cases in which the struck vehicle was a “passenger car or truck” and “ordinary or light” was 155,502, or approximately 99%. The number of rear-end collisions in which the struck vehicle was an ordinary passenger car was 162,521, or approximately 62%, and, of them, the number of cases in which the striking vehicle was a “passenger car or truck” and “ordinary or light” was 158,129, or approximately 97%. These figures indicate that many of the striking and struck vehicles were ordinary passenger cars and that most of the other parties were passenger cars or trucks and were ordinary or light vehicles. Accordingly, the target vehicles for the subsequent analyses were limited to ordinary passenger cars whose other parties were passenger cars or trucks and were ordinary or light vehicles.

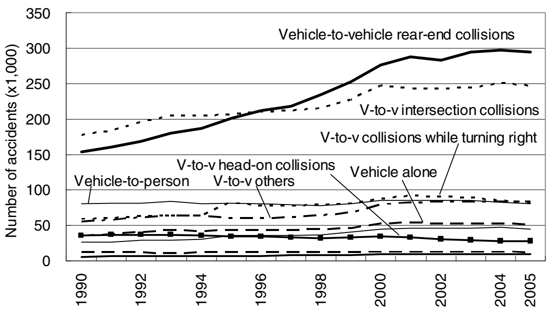

Figure 2. Trends in traffic accidents by type of accident.

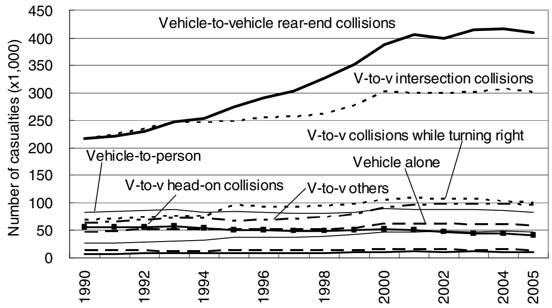

Figure 3. Trends in traffic accident casualties by type of accident.

Table 1.
Number of rear-end collisions between vehicles by vehicle classification (2005)

			Striking vehicle (primary party)								
			Passenger car				Truck			Special vehicle	Total
			Bus, Minibus	Ordinary	Light	Mini-car	Large-sized special, Large-sized	Ordinary	Light		
Struck vehicle (secondary party)	Passenger car	Bus, Minibus	25	224	61	0	30	107	24	1	472
		Ordinary	414	100,049	26,782	2	3,927	20,962	10,336	49	162,521
		Light	108	33,330	12,428	0	1,073	6,003	4,413	24	57,379
		Mini-car	0	1	3	3	0	2	3	0	12
	Truck	Large-sized special, Large-sized	9	482	154	0	733	564	92	0	2,034
		Ordinary	69	10,361	2,489	1	1,296	4,568	1,329	11	20,124
		Light	57	11,762	3,997	0	528	3,070	1,774	10	21,198
	Special vehicle		3	115	48	0	15	36	36	0	253
	Total		685	156,324	45,962	6	7,602	35,312	18,007	95	263,993

Injuries Incurred by Ordinary-passenger-car Occupants in Rear-end Collisions

The injuries incurred by ordinary-passenger-car occupants in rear-end collisions in 2005 were analyzed in the striking and struck vehicles respectively under the following assumptions:

- Target vehicles for analysis: ordinary passenger cars
- Other-party vehicle: passenger car or truck and ordinary or light vehicle
- Striking vehicle: primary party (culpable)
- Struck vehicle: secondary party (less culpable) and struck in the entire rear-end area
- Multiple collision: excluded

The first analysis focused on the drivers. Figure 4 shows that approximately 99% of the 119,678 striking-vehicle drivers were not injured. In contrast, approximately 87% of the 124,172 struck-vehicle drivers were slightly injured, mainly in the neck, as shown in Figure 5. This suggests that attention should be paid to neck injuries in struck vehicles in rear-end collisions. On the other hand, approximately 73% of the 148,423 struck-vehicle occupants who mainly suffered neck injuries were drivers, approximately 17% of them were front-seat passengers and approximately 10% of them were rear-seat passengers as shown in Figure 6. These figures indicate that neck injuries of struck-vehicle drivers have a high priority.

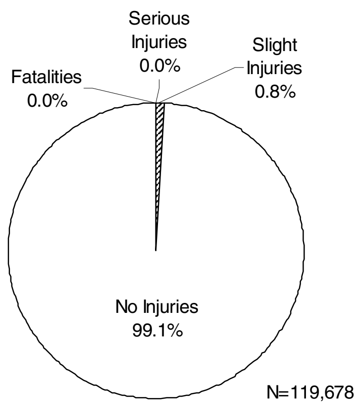

Figure 4. Injury severities of striking-vehicle drivers in rear-end collisions (ordinary passenger cars, primary parties, 2005).

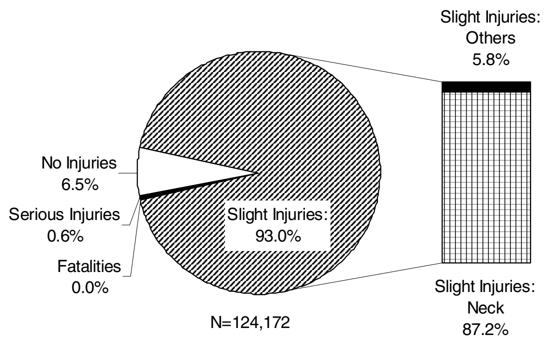

Figure 5. Injury severities of struck-vehicle drivers in rear-end collisions (ordinary passenger cars, secondary parties, 2005).

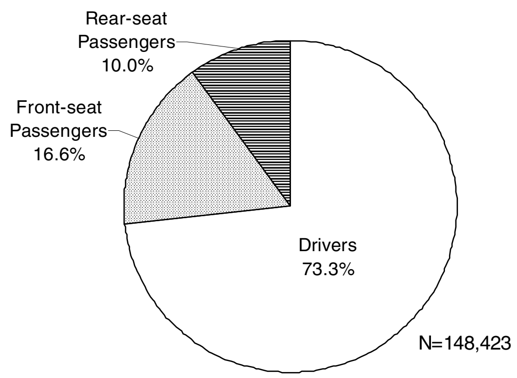

Figure 6. Seating positions of all occupants of struck vehicles in rear-end collisions (ordinary passenger cars, secondary parties, neck injured, 2005).

Neck Injury Incidence in Rear-end Collision

Measures to prevent whiplash neck injuries in struck vehicles are desired. However, the mechanism of whiplash injuries is not fully understood at present, and there are differing opinions about the mechanism causing such injuries [4-8].

DEFINITION OF NO-NECK-INJURY RATE

An analysis was made of the relation of struck-vehicle properties to neck injuries in struck vehicles, which account for the greater portion of rear-end collision casualties. The index used in the analysis was the no-neck-injury rate defined as follows, based on the injury severity of struck-vehicle drivers:

$$\text{No-neck-injury rate (\%)} = \frac{\text{No injuries}}{\text{Fatalities+ Serious/Slight injuries+ No injuries}} \times 100$$

Casualties (fatalities, serious injuries and slight injuries) were restricted to those that mainly involved neck injuries. The types of serious and slight injuries were limited to sprains, dislocations or fractures in order to focus on injuries thought to be whiplash or an extension thereof. It will be noted that this index is used only for drivers because only drivers, as a rule, are counted among the no-injury vehicle occupants in ITARDA's integrated accident database.

INFLUENCE OF STRUCK-VEHICLE PROPERTIES

The struck-vehicle properties analyzed in this study with this index were the initial year of registration and presence/absence of an anti-whiplash device.

Relation to Initial Year of Registration

__Method and Data__ - An investigation was made of whether neck injuries were apt to occur in newer struck vehicles, in view of the upward trend for casualties in rear-end collisions as shown in Figure 3. The relationship between the initial year of registration and the no-neck-injury rate of drivers in struck vehicles was analyzed using the integrated accident database. Each passenger car class was analyzed separately because the differing shapes and weights of different vehicle classes would affect the no-neck-injury rate. The definitions of the passenger car classes used by ITARDA are shown in Table 2. The analysis focused on rear-end collisions in 2004 that met the following conditions:

- Struck vehicle: secondary party and struck in the entire rear-end area
- Striking vehicle: passenger car or truck, ordinary or light , and primary party
- Multiple collision: excluded

__Results__ - The results in Figure 7 show that there was no tendency for the no-neck-injury rate of struck-vehicle drivers to decrease with a later initial year of registration of the struck vehicle. On the contrary, for the Sedan-B class (engine displacement of 1500-2000 cc) and the Sedan-C class (engine displacement of over 2000 cc), the no-neck-injury rate tended to increase with a later initial year of registration of the struck vehicle.

Table 2.
Definitions of passenger car classes

Passenger car class
Family-Light
Sedan-A (engine displacement of under 1500 cc)
Sedan-B (engine displacement of 1500-2000 cc)
Sedan-C (engine displacement of over 2000 cc)
Sports & Speciality
Wagon
1-Box & Minivan
SUV (Sport-utility vehicle)

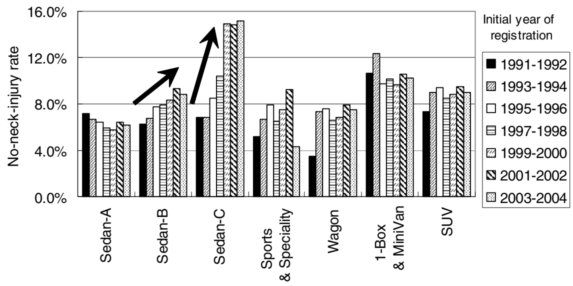

Figure 7. Relationship between no-neck-injury rate and initial year of registration of struck vehicles in rear-end collisions (ordinary passenger cars, secondary parties, 2004).

Effect of an Anti-whiplash Device: Analysis Based on No-neck-injury Rate

__Method and Data__ - To examine the effect of an anti-whiplash device, which has been spreading in recent years, vehicle models meeting the following requirements were selected, and the difference in the no-neck-injury rate between drivers of vehicles with and without such a device was analyzed.

- Ordinary passenger car with and without an anti-whiplash device (To exclude body influences such as the crash characteristics of the rear end)
- The device is not an option. (To eliminate driver consciousness of whiplash)
- Presence of the device can be clearly distinguished according to the model code. (To calculate the no-neck-injury rate in the presence of the device)
- Vehicle models with and without the device were put on the market by 1999. (To secure a sufficient volume of accident data)

Only one vehicle model meeting these requirements was found. This vehicle was Sedan-C put on the market in 1996. The anti-whiplash device fitted on this vehicle was an active head restraint (AHR) system [9]. An AHR system was not provided initially and became standard equipment on all models of this vehicle in the latter half of 1998.

The analysis focused on rear-end collisions occurring over five years from 2000 to 2004 and meeting the following conditions:

- Struck vehicle: the above-mentioned vehicle model, struck in the entire rear-end area, and secondary party
- Striking vehicle: passenger car or truck, ordinary or light, and primary party
- Multiple collision: excluded

Results - Under the conditions above, the numbers of drivers incurring mainly neck injuries or no injuries in this vehicle are shown in Table 3. Of 760 drivers, 105 suffered neck injuries with the AHR and 21 reported no injuries, whereas 587 incurred injuries without the AHR and 47 reported no injuries. The no-neck-injury rate with the AHR (16.7%) was higher than that without the AHR (7.4%) as shown in Table 3 and Figure 8.

A two-sample test for equality of proportions was conducted between these no-neck-injury rates. The test statistic Z is given by:

$$Z = | p_1 - p_2 | / \sqrt{p(1 - p)(1/n_1 + 1/n_2)}$$

where,

$$p = (n_1p_1 + n_2p_2) / (n_1 + n_2)$$

According to these formulas, Z was 3.324, which means that the P-value in the two-sided test was 0.0009. These figures show that the no-neck-injury rate with the AHR was higher than that without the AHR at the 1% significance level.

Table 3.
Incidence of casualties and no injuries with/without AHR and results of statistical analysis

	with AHR	w/o AHR
Fatal neck injuries	0	0
Serious neck injuries (sprains, dislocations, fractures)	1	4
Slight neck injuries (sprains, dislocations, fractures)	104	583
No injuries/ Overall	21	47
Total	126	634
No-neck-injury rate	16.7%	7.4%
Z-statistic	3.324	
P-value	0.0009 (<0.01)	

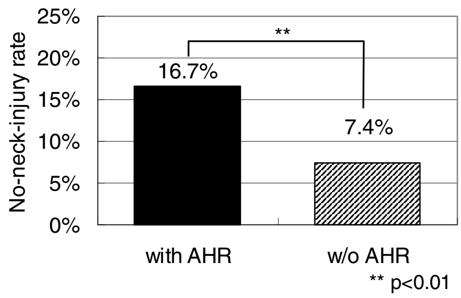

Figure 8. Influence of AHR on no-neck-injury rate.

Results of Additional Analysis Following Classification of Factors - In the preceding discussion, it was statistically confirmed that the presence of an AHR influences the no-neck-injury rate. However, other factors that might influence the incidence of neck injuries in rear-end collisions, such as impact severity, gender and age, were not considered. For that reason, an investigation was made of whether there was a large difference in the composition of the factors in relation to the presence of an AHR. The results are shown in Figures 9 to 11. Pseudo-ΔV [10] is used as an index in Figure 9 to indicate the impact severity in a rear-end collision. Pseudo-ΔV of a struck vehicle can be calculated with the following equation, based on the struck-vehicle impact speed V_1, struck-vehicle weight M_1, striking-vehicle impact speed V_2 and striking-vehicle weight M_2 as shown in Figure 12.

$$\text{Pseudo-}\Delta V = V - V_1$$

$$= (M_1V_1 + M_2V_2) / (M_1 + M_2) - V_1$$

$$= (V_2 - V_1) M_2 / (M_1 + M_2)$$

Here, V means the speed of both vehicles after a rear-end collision and is assumed as follows:

- The coefficient of rebound is 0 (e = 0).
- The impact speed is equal to the speed reported by the driver.
- The vehicle weight is equal to the unladen vehicle weight.

The results in Figures 9 to 11 indicate that there was no large difference in the composition of these factors due to the presence of an AHR, so it can be concluded that the factors did not influence the no-neck-injury rate. Moreover, after classifying the 760 persons in Table 3 separately according to each factor, additional analyses were conducted for the sake of reference.

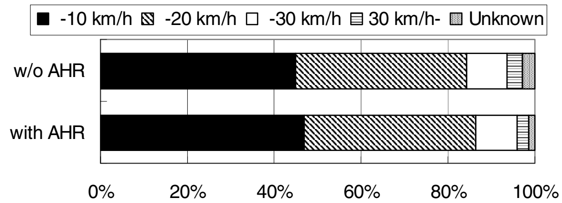

Figure 9. Distribution of pseudo-ΔV with/without AHR.

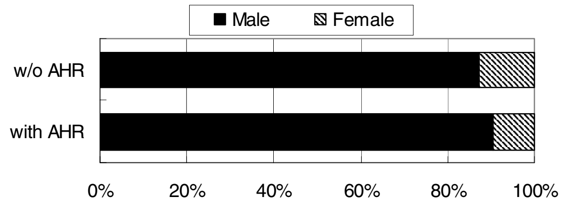

Figure 10. Distribution of gender with/without AHR.

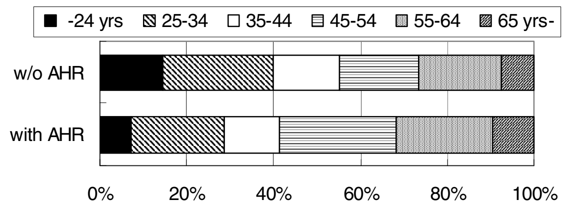

Figure 11. Distribution of age with/without AHR.

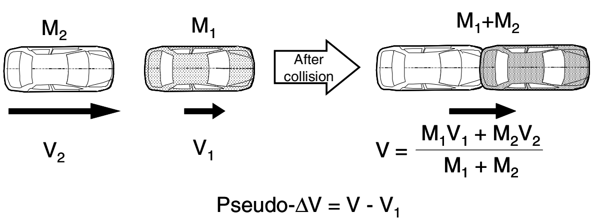

Figure 12. Definition of pseudo-ΔV.

The results of a comparison of the no-neck-injury rate according to the presence of an AHR in each group into which the 760 persons were divided on the basis of pseudo-ΔV are shown in Figure 13. It is seen that the no-neck-injury rate with an AHR was statistically higher than that without an AHR for the 0–10 km/h group and the 11–20 km/h group that accounted for the majority of the 760 persons. It was significantly higher at the 5% significance level for the 0–10 km/h group. For the 11–20 km/h group, it was significantly higher at the 1% significance level. As for the 21–30 km/h group, it is observed that the no-neck-injury rate with an AHR was higher than that without an AHR, but no statistically significant difference can be confirmed because of the limited data. As a whole, it can be concluded that the no-neck-injury rate with an AHR was higher than that without an AHR even when the influence of the impact severity in the collision was eliminated.

Figure 14 presents the results for the no-neck-injury rate when a comparison was made by gender in relation to the presence of an AHR, after the 760 persons were distinguished by gender. For males, it was confirmed that the no-neck-injury rate with an AHR was higher than that without an AHR at the 1% significance level. As for females, the no-neck-injury rate with an AHR was higher than that without an AHR, though no statistically significant difference can be confirmed because of the limited data. Overall, it can be inferred that the no-neck-injury rate with an AHR was higher than that without an AHR even after excluding the influence of gender.

Figure 15 shows that the no-neck-injury rate with an AHR was higher than that without an AHR for each age group into which the 760 persons were divided according to age (Figure 11). A statistically significant difference was confirmed only for the 24-or-younger group at the 1% significance level, because of the limited data for the other groups. Considering the group from 25 to 64 years old, the no-neck-injury rate with an AHR was also higher than that without an AHR at the 5% significance level as shown in Figure 16. On the whole, it would appear that the no-neck-injury rate with an AHR was higher than that without an AHR even when the influence of age was removed.

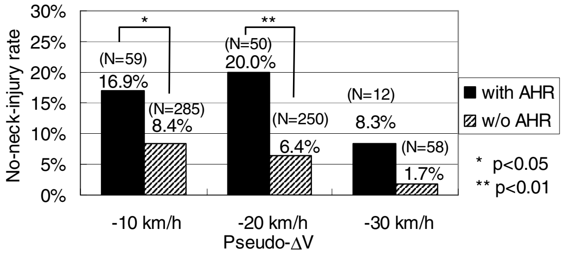

Figure 13. Influence of AHR on no-neck-injury rate by pseudo-ΔV.

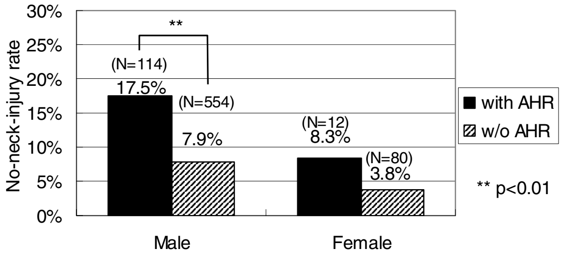

Figure 14. Influence of AHR on no-neck-injury rate by gender.

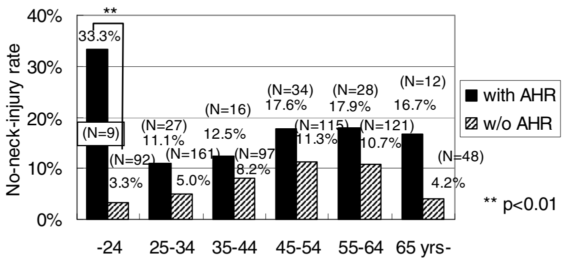

Figure 15. Influence of AHR on no-neck-injury rate by age (divided into six age groups).

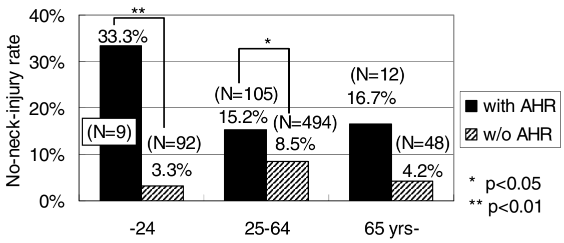

Figure 16. Influence of AHR on no-neck-injury rate by age (divided into three age groups).

Effect of an Anti-whiplash Device: Regression Analysis

Method and Data - In the preceding analysis, the influence of each factor was separately excluded when the no-neck-injury rate was calculated in order to analyze the effect of an AHR. A regression analysis was then conducted in which all of the factors, including the presence/absence of an AHR, were treated at the same time. As the neck injury severity is a qualitative variable and also a ranked variable, an ordered response model was used in the analysis [11]. It was decided to treat the neck injury severity as a binary response of neck injuries (fatalities, serious or slight injuries principally to the neck) or no injuries. An explanation is given here of the method for conducting a regression analysis using an ordered response model. With an ordered response model, it is assumed that there is a latent factor Y^*_i which is a continuous variable that determines whether the neck injury severity Y_i is 1 (neck injury) or 0 (no injury). In this analysis, it is assumed that there is a linear relation between the continuous latent factor Y^*_i indicating the neck injury severity and the explanatory variables, including $X_{k,i}$ (k=1,2,3, …), pseudo-ΔV, which are considered as independent variables. Then, Y^*_i can be expressed with the following equations.

$$Y^*_i = z_i + \varepsilon_i$$

$$z_i = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \beta_3 X_{3,i} + \ldots + \beta_k \mathrm{Pseudo}\Delta V$$

where,

$$Y_i = \begin{cases} 1 \text{ (neck injury): in the case of } Y^*_i > 0 \\ 0 \text{ (no injury): in the case of } Y^*_i \leq 0 \end{cases}$$

z_i is a value which can be explained by $X_{1,i}$, $X_{2,i}$, $X_{3,i}$, …, $X_{k,i}$ and pseudo-ΔV. ε_i is a residual value. $X_{1,i}$, $X_{2,i}$, $X_{3,i}$, …, $X_{k,i}$ are explanatory variables and have a value of either 0 or 1 if they are dummy variables. β_0, β_1, β_2, β_3, …, β_k are constant values which express the degree of influence of each explanatory variable on Y^*_i. The cumulative distribution function F of $-\varepsilon_i$ is assumed to be the logistic distribution given in the following equation.

$$F = e^z / (1 + e^z)$$

Here, the explanatory factors are with/without an AHR, gender (male, female), age (24 years or younger, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65 years or older) and pseudo-ΔV. These factors, except pseudo-ΔV, are treated as dummy variables which have a value of either 0 or 1. A combination of without an AHR, male and 24 years or younger is assumed to be the standard combination, and the analysis is conducted. Concretely, k is set from 0 to 8, and $X_{1,i} = X_{2,i} = \ldots = X_{7,i} = 0$ in the standard combination. $X_{1,i} = 1$ with an AHR. $X_{2,i} = 1$ in the case the gender is female. $X_{3,i} = 1$ when the age is 25-34 years, $X_{4,i} = 1$ when 35-44 years, $X_{5,i} = 1$ when 45-54 years, $X_{6,i} = 1$ when 55-64 years, and $X_{7,i} = 1$ when the age is 65 years or older.

The data for 21 of the 760 persons extracted in the preceding analysis were omitted in this analysis because of uncertain pseudo-ΔV. The data of the remaining 739 persons were used in the regression analysis conducted with the ordered response model. The constant values of β_0, β_1, β_2, β_3, ..., β_8 were estimated by the maximum likelihood method, using the TSP 5.0 statistical analysis software [12].

Results - The results of the analysis are presented in Table 4 and Figure 17. The estimated values are the results of an estimation of the coefficient β_k. A likelihood ratio test was carried out to evaluate the null hypothesis, assuming that all the estimated values were equal to 0. The 2LL result of this test was 22.85, which was statistically significant because it was larger than 20.1 of the 1% chi-square of 8 degrees of freedom. The fraction of correct predictions was 0.912. Therefore, it can be concluded that the regression equation consisting of the explanatory variables such as with/without an AHR, gender, age and pseudo-ΔV is significant.

As for the effect of an AHR, the estimated coefficient with an AHR was negative at -0.871, and the t-statistic was -2.97, which satisfied the 1% significance level in the two-sided test. This indicates that Y^*_i becomes smaller and that the possibility of no injury increases when an AHR is installed.

Table 4.
Estimated results of regression analysis using an ordered response model (Standard=without AHR, male, 24 years or younger)

			Estimated	Std. Error	t-statistic	P-value	
Constant		β_0	2.417	0.472	5.115	0	
with AHR		β_1	-0.871	0.293	-2.970	0.003	**
Female		β_2	0.800	0.539	1.483	0.138	
Age	25-34 yrs	β_3	0.108	0.537	0.202	0.840	
	35-44 yrs	β_4	-0.514	0.542	-0.949	0.342	
	45-54 yrs	β_5	-0.785	0.497	-1.579	0.114	
	55-64 yrs	β_6	-0.564	0.504	-1.119	0.263	
	65 yrs or older	β_7	-0.018	0.678	-0.026	0.979	
Pseudo-ΔV(km/h)		β_8	0.036	0.019	1.834	0.067	

Number of observations = 739　　Fraction of correct predictions = 0.912
Log likelihood L = -208.639　　Log likelihood L_0 = -220.063
2LL= 22.85　　** : p<0.01

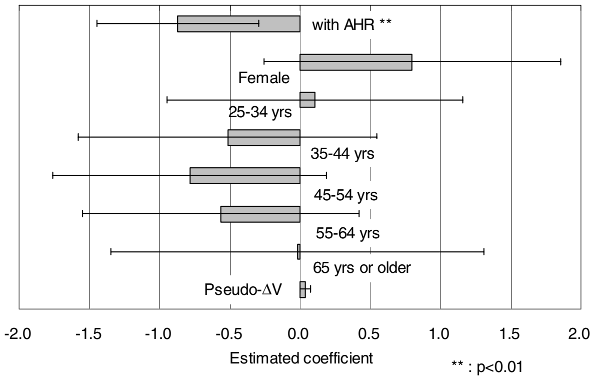

Figure 17. Estimated coefficients and 95% confidence intervals.

INFLUENCE OF HUMAN ATTRIBUTES OF STRUCK-VEHICLE DRIVERS

Regression Analysis

Method and Data - A regression analysis was conducted to examine the influence of human attributes, such as gender, age and trip purpose, on the incidence of neck injuries suffered by the drivers of the struck vehicles in rear-end collisions. The vehicles considered in the analysis were ordinary passenger cars of the Sedan-A class (engine displacement of under 1500 cc) in the passenger car classes (Table 2). The accidents analyzed were limited to rear-end collisions in 2004 between vehicles that met the following conditions:

- Struck vehicle: secondary party and struck in the entire rear-end area
- Striking vehicle: passenger car or truck, ordinary or light , and primary party

- Multiple collision: excluded
- Pseudo-ΔV of the struck vehicle: 30 km/h or less.

The Sedan-A class was selected as the target vehicle category for analysis because it accounted for the largest number of accidents of the above-mentioned type among the seven classes of ordinary passenger cars (excluding Family-Light) in Table 2. It was also confirmed that the pseudo-ΔV of the Sedan-A class was 30 km/h or less in more than 90% of the cases.

Among the rear-end collisions analyzed, there were a total of 18,718 cases in which the driver of the struck vehicle mainly suffered a neck injury or was not injured. In order to restrict neck injuries to those presumed to be whiplash or an extension thereof, as was done in the analysis of vehicle properties, the types of serious and slight injuries treated here were limited to sprains, dislocations or fractures.

Similar to the analysis of vehicle properties, an ordered response model was used to conduct a regression analysis of the data for the 18,718 struck-vehicle drivers. The objective variable used in the analysis was neck injury severity, which was treated in terms of a binary response of neck injuries or no injuries.

The explanatory variables used were gender (male or female), age group (six age groups of 24 years or younger, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65 years or older), trip purpose (private trip, business trip, commuting to work, commuting to school) and pseudo-ΔV. Twelve combinations of gender and age (2x6=12) were considered: male/24 years or younger, male/25-34 years, male/35-44 years, …, female/55-64 years, and female/65 years or older. These twelve combinations and trip purpose were treated as dummy variables having a value of either 0 or 1. A combination of male/24 years or younger and a private trip was regarded as the standard combination in conducting the analysis. Specifically, in the regression equation formulated for the analysis of vehicle properties, k was set at values from 0 to 15, and $X_{1,i} = X_{2,i} = \ldots = X_{13,i} = X_{14,i} = 0$ was set in the standard combination. For the combination of male/25-34 years, $X_{1,i} = 1$, for male/35-44 years, $X_{2,i} = 1$, …, for female/55-64 years, $X_{10,i} = 1$ and for female/65 years or older, $X_{11,i} = 1$. With respect to the trip purpose, $X_{12,i} = 1$ for a business trip, $X_{13,i} = 1$ for commuting to work and $X_{14,i} = 1$ for commuting to school.

Results - The results of the regression analysis are shown in Table 5 and Figure 18. A likelihood ratio test of the regression equation produced a 2LL result of 613.4, which satisfied the 30.6 value of the 1% chi-square for 15 degrees of freedom. It can be concluded therefore that the regression equation consisting of the explanatory variables of gender, age group, trip purpose and pseudo-ΔV was significant. The fraction of correct predictions was 0.936.

Table 5.
Estimated results of regression analysis using an ordered response model (Standard=male/24 years or younger, private trip)

			Estimated	Std. Error	t-statistic	P-value	
Constant		β_0	2.031	0.137	14.806	0.000	**
Gender, Age	Male, 25-34 yrs	β_1	0.133	0.149	0.893	0.372	
	Male, 35-44 yrs	β_2	-0.058	0.154	-0.373	0.709	
	Male, 45-54 yrs	β_3	-0.221	0.155	-1.426	0.154	
	Male, 55-64 yrs	β_4	-0.482	0.146	-3.293	0.001	**
	Male, 65 yrs or older	β_5	-0.704	0.147	-4.799	0.000	**
	Female, 24 yrs or younger	β_6	0.457	0.188	2.424	0.015	*
	Female, 25-34 yrs	β_7	1.191	0.183	6.503	0.000	**
	Female, 35-44 yrs	β_8	0.665	0.172	3.865	0.000	**
	Female, 45-54 yrs	β_9	0.629	0.163	3.858	0.000	**
	Female, 55-64 yrs	β_{10}	0.825	0.182	4.531	0.000	**
	Female, 65 yrs or older	β_{11}	1.037	0.290	3.573	0.000	**
Purpose	Business trips	β_{12}	0.954	0.132	7.250	0.000	**
	Commuting to work	β_{13}	1.665	0.151	11.013	0.000	**
	Commuting to school	β_{14}	1.536	1.013	1.516	0.129	
Pseudo-ΔV(km/h)		β_{15}	0.019	0.004	4.324	0.000	**

Number of observations = 18,718 Fraction of correct predictions = 0.939
Log likelihood L = -4142.53 Log likelihood L_0 = -4449.24
2LL= 613.41 * p<0.05 ** p<0.01

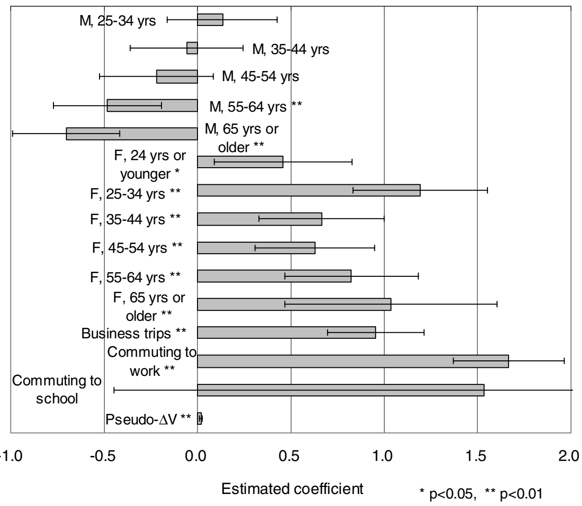

Figure 18. Estimated coefficients and 95% confidence intervals.

Comparisons were then made with the standard combination (male/24 years or younger) with respect to gender and age group. The estimated regression coefficients for male/55-64 years and male/65 years or older were negative at -0.482 and -0.704, respectively, and both values satisfied the 1% significance level in a two-sided test. This indicates that for males aged 55 years or older, Y^*_i becomes smaller, which means the possibility of no neck injury increases. The estimated regression coefficients for all the female age groups were positive, and all the values satisfied the 1% significance level in a two-sided test. Looking at the results for males and females in general, female drivers showed much larger, positive regression coefficients than their male counterparts, which suggests that female drivers of struck vehicles have a higher likelihood of suffering a neck injury in a rear-end collision. Focusing on differences attributable to the age group among females, no pronounced tendencies are seen. It can be inferred that age did not have any appreciable influence on the overall results.

Trip purposes were compared with the standard of private trips. Business trips and commuting to work showed positive estimated regression coefficients of 0.954 and 1.665 respectively. Both values satisfied the 1% confidence level in a two-sided test. These values indicate that Y^*_i becomes larger for business trips and commuting to work, compared with private trips, which means there is a greater possibility of suffering a neck injury. No significant difference was observed for commuting to school.

The foregoing analysis results can be summed up as follows:

a. Females are more likely to be injured than males.
b. Younger males are more likely to be injured than older ones.
c. Age does not have any influence in the case of females.
d. Drivers are more likely to be injured on business trips or when commuting to work than on private trips.

Cohort Analysis

<u>Method and Data</u> - It is known that when occupants are injured in a traffic accident, their likelihood of suffering a fatal or serious injury increases with age. The reason for that is attributed to an aging-related decline in the body's tolerance of the shock or force resulting from an impact [13-15]. Among the results of the regression analysis described above, the finding noted in (b) "younger males are more likely to be injured than older ones" would seem to run counter to that general trend. Nearly all of the accident cases analyzed involved slight neck injuries, which need not be viewed in the same light as fatal or serious injuries. Nonetheless, this contrary tendency aroused interest because of its seeming peculiarity. It was presumed that some other latent factor besides age was at work here. In order to examine that hypothesis, a cohort analysis was conducted separately for males and females.

The struck vehicles considered in the analysis were ordinary passenger cars of the Sedan-A class in the passenger car classes. The accidents analyzed were limited to rear-end collisions in 2004 between vehicles that satisfied the following conditions:

- Struck vehicle: secondary party and struck in the entire rear-end area
- Striking vehicle: passenger car or truck, ordinary or light , and primary party
- Multiple collision: excluded

The birth year of the struck-vehicle drivers was defined as the year obtained by subtracting the person's age at the time of the accident from the year in which the accident occurred. On the basis of their birth year, struck-vehicle drivers were divided into age groups in four-year increments. A time history of the no-neck-injury rate in rear-end collisions was found for each age group at four-year intervals of 1992, 1996, 2000 and 2004.

<u>Results</u> - The cohort analysis results are shown separately for males and females in Figures 19 and 20, respectively. A comparison of the results for the two genders shows that the no-neck-injury rate was lower for females in general. This provides additional confirmation of the regression analysis finding noted above in (a) "females are more likely to be injured than males".

For males with a birth year of 1951 or earlier (referred to here as the older generation), the time histories of their no-neck-injury rate did not show much change or revealed a rising trend. The histories nearly overlapped one another and showed continuity (circle A in Figure 19). Accordingly, it was concluded that, within this older generation, the time history patterns of the no-neck-injury rate did not differ appreciably from one age group to another.

On the other hand, for males having a birth year of 1952 or after (referred to here as the younger generation), the time histories of their no-neck-injury rate revealed a downward trend. The histories did not overlap and discontinuities were seen (circle B in Figure 19). The patterns differed from those of the older generation. In other words, the time histories of the no-neck-injury rate showed different patterns between the generations.

This suggests that one cannot make a simple assertion based only on age that "younger males are more likely to be injured than older ones", as mentioned in (b) in the summary above. It can be inferred that generational and time period differences, including related traffic and societal circumstances, also probably exert an influence on neck injuries in rear-end collisions. It is presumed that such influence gave rise to the tendencies seen in the cohort analysis results for the younger generation to have a lower no-neck-injury rate than the older generation and for that trend to become more pronounced with increasing age.

For females, the no-neck-injury rates in Figure 20 are nearly constant regardless of age or generation, excluding the results for those aged 69 years or older, for which large scatter is seen because of the small number of data. These results provide additional confirmation of the regression analysis finding mentioned above in (c) "age does not have any influence in the case of females". Moreover, the results also show virtually no influence of generation, a tendency that differs from the results seen for males.

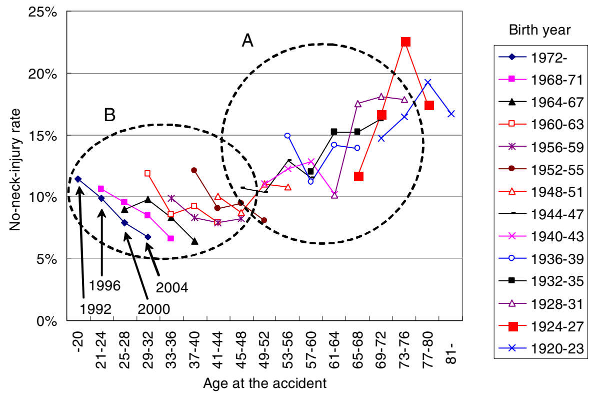

Figure 19. No-neck-injury rate by age and birth year for males (Sedan-A class, secondary parties).

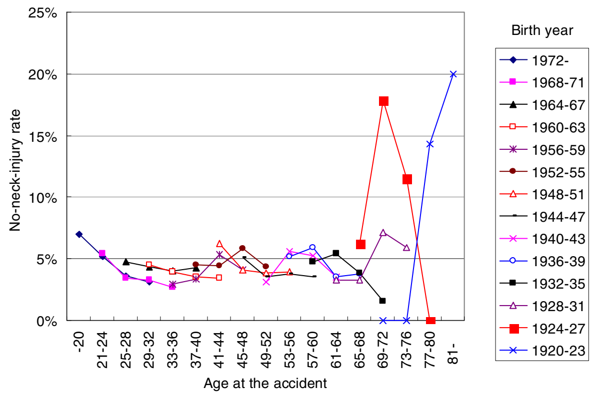

Figure 20. No-neck-injury rate by age and birth year for females (Sedan-A class, secondary parties).

For the sake of reference, nearly the same tendencies were found when the same analysis was performed for the other passenger car classes, with the exception of large scatter that was observed for a small number of cases.

Discussion of the Influence of Human Attributes of Struck-vehicle Drivers

Human attributes such as gender, age, generation and trip purpose were shown to influence the incidence of neck injuries in rear-end collisions. From a biomechanics perspective, it is easy to understand that gender or age might influence the incidence of neck injuries inasmuch as the body's tolerance of the resultant impact severity or force of a collision can vary depending on differences in these attributes. On the other hand, an attempt to discuss the influence of generation from a biomechanics standpoint lacks persuasiveness, although one can consider, for example, that the body's tolerance may change depending on variation in such factors as the living environment or diet. Moreover, the influence of the trip purpose can no longer be discussed from a biomechanics perspective. It might be more appropriate to assume that the influence of generation or trip purpose is due to some reason other than biomechanics considerations.

This investigation focused on whether neck injuries occurred or not in rear-end collisions. Injuries requiring long-term care and those involving simply an examination by a doctor just to be on the safe side were both treated in the same manner. Consequently, the findings may have been influenced by the health consciousness of the parties involved. If that led to the results seen concerning the influence of generation or trip purpose on the incidence of neck injuries, it would make such tendencies easier to understand. Earlier studies [16-18] pointed out the possibility of results being influenced by the health consciousness of the parties involved, and such a possibility certainly cannot be ruled out in this study that looked at whether injuries occurred or not. However, it is a fact that many people incur neck injuries in rear-end collisions or suffer from subsequent complications. It is strongly felt that all of neck injuries should not be ascribed simply to the health consciousness of the parties involved in the accidents.

If the no-neck-injury rate tendency seen here for males of the younger generation continues in the future, it will cause the rate to decline for males in general. Unless measures are taken to prevent neck injuries in rear-end collisions, there is concern that the incidence of such injuries may increase in the coming years.

CONCLUSION

The following results were obtained in this analysis of neck injuries in rear-end collisions in Japan using the integrated accident database developed by ITARDA.

Regarding Struck-vehicle Properties

- It was shown that the no-neck-injury rate of struck-vehicle drivers did not tend to decrease with a later initial year of registration of the struck vehicles. On the contrary, in some passenger car classes, the no-neck-injury rate tended to increase with a later initial year of registration of the struck vehicles.
- After eliminating various factors which were thought to influence the incidence of neck injuries, it was found that an active head restraint (AHR) system, which is one type of anti-whiplash device, was effective in suppressing the incidence of neck injuries in struck-vehicle drivers, though the verification was based on just one vehicle model. The various factors eliminated were the crash characteristics of the struck vehicle, impact severity estimated from the weight and impact speed of the striking and struck vehicles, and drivers' gender, age and consciousness of whiplash.

Regarding the Human Attributes of Struck-vehicle Drivers

- Females were more likely to be injured than males.
- For males, age and generation influenced the incidence of neck injuries. The younger generation (those having a birth year of 1952 or later) were more likely to be injured than the older generation (having a birth year before 1952), and that tendency became even stronger as they grow older.
- For females, age and generation did not show any influence.
- The trip purpose exerted an influence in that drivers were more likely to be injured on business trips or while commuting to work than on private trips.
- Among these findings, the influence of generation and trip purpose was difficult to explain from a biomechanics perspective. There was a possibility that the health consciousness of the parties involved influenced whether some injuries were reported or not. However, it is indisputable that many people incur neck injuries in rear-end collisions or suffer from subsequent complications. There is a strong feeling that all of neck injuries should not be ascribable merely

to the health consciousness of the parties involved.

- If the tendency seen for the no-neck-injury rate of males continues in the future, there is concern that the incidence of neck injuries may increase in the coming years.

The incidence of no injuries in property damage accidents are not reflected in the no-neck-injury rate used in this study because of limitations of the integrated accident database. The accuracy of analyses based on the no-neck-injury rate could be further improved by using a database that included the incidence of no injuries in property damage accidents such as the database of the automobile insurance industry.

There is also a need to undertake studies based on data for more narrowly defined injury severity categories, such as investigations that focus on the number of days required for treatment, for example. Such an approach might yield insights that reduce the possible influence of the health consciousness of the parties involved.

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